Reprinted from "Bulletin of Marine Science" Volume 61, 1997, pp. 671-683, Manooch and Potts: Age, Growth, and Mortality of greater Amberjack, Seriola dumerili, from the U.S. Gulf of Mexico Headboat Fishery. With permission from Rosenstiel School of Marine and Atmospheric Science of the University of Miami.

BULLETIN OF MARINE SCIENCE, 61(3): 671–683, 1997

AGE, GROWTH, AND MORTALITY OF GREATER AMBERJACK, *SERIOLA DUMERILI*, FROM THE U.S. GULF OF MEXICO HEADBOAT FISHERY

Charles S. Manooch, III and Jennifer C. Potts

ABSTRACT

Sectioned otoliths (saggitae) from 340 greater amberjack, *Seriola dumerili*, 305-1512 mm total length (270-1355 mm fork length) were examined. The fish were sampled from recreational headboats operating in the Gulf of Mexico from Naples, Florida, to Port Aransas, Texas, from 1988 to 1993, and therefore, best represent age and growth of the species as harvested by this fishery. Most (53%) of the fish were landed in Texas, but others came from northwest Florida and Alabama (46%) and Louisiana (1%). The oldest fish was estimated to be age 15 and measured 1512 mm total length (1355 mm fork length). Rings formed on most otoliths between March and May, and are thus considered to be true annual marks. Back-calculated mean total lengths for 225 fish were 415, 614, 742, 839, 915, 976, 1044, 1100, 1156, 1209, 1256, 1283, 1299, 1332, and 1365 mm for ages 1 through 15, respectively. Equations were derived to convert lengths: FL = -17.7319 + 0.8847(TL), and TL = 24.2327 + 1.1247(FL). Back-calculated lengths at age were used to derive the following von Bertalanffy growth equations: $TL_t = 1272\,(1\text{-}e^{-0.2272(t+0.7931)})$, and $FL_t = 1109\,(1\text{-}e^{-0.2270(t+0.7198)})$. Greater amberjack are fully recruited to the headboat fishery in the Gulf of Mexico at age 4. Total instantaneous mortality estimates (Z) generated from catch curves of the Gulf of Mexico headboat fishery were 0.68 for 1988 and 0.70 for 1993.

There are many species in the family Carangidae that are important to fisheries. The Florida pompano, *Trachinotus carolinus*, is perhaps the most popular, but other carangids such as the greater amberjack, *Seriola dumerili*, almaco jack, *S. rivoliana*, banded rudderfish, *S. zonata*, lesser amberjack, *S. fasciata*, blue runner, *Caranx crysos*, crevalle jack, *C. hippos*, bar jack, *C. ruber*, permit, *Trachinotus falcatus*, and African pompano, *Alectis ciliaris*, are all excellent game fish.

The four species of *Seriola* occur in the western Atlantic and are similar in appearance, at least at certain sizes, but may be distinguished by the length of the anal fin base, number of gill rakers, and number of spines and rays in the dorsal fins (Manooch, 1984), and color pattern. One of the largest, the greater amberjack, occurs in the Mediterranean Sea and the Atlantic, Pacific, and Indian Oceans. In the western Atlantic, greater amberjack are distributed from Nova Scotia to Brazil, including the Gulf of Mexico and the Caribbean, where they congregate around reefs, rock outcrops, and wrecks. Smaller individuals (<1m) are usually found in waters less than 10 m in depth, whereas larger specimens (the species attains 73 kg) generally occur in waters 18-72 m deep. The species has been recorded in depths to 360 m (Fischer, 1978).

Limited localized information is available on the life history of the greater amberjack. The most comprehensive studies to date are M.S. theses on the life history of the species off southeastern Florida (Burch, 1979) and Louisiana (Beasley, 1993). Manooch (1984) briefly summarized age, growth, reproduction, and feeding of the species for the southeastern United States. In this paper we present data on age and growth of greater amberjack collected in the Gulf of Mexico: validation of rings on otoliths as annuli, fish lengths at capture by age, back-calculated fish lengths by ages, theoretical growth parameters and lengths at ages, fish length-fish age keys, and estimates of mortality. These data and analyses are necessary to assess the status of the greater amberjack in the Gulf of Mexico.

In recent years the greater amberjack has become an important commercial species and is an established favorite of recreational anglers. Recreational fishermen catch the species from anchored or drifting boats using live fish or cut squid or fish as baits, and by trolling with spoons and other deep- running artificial lures (Manooch, 1984). Commercial fishermen harvest amberjacks with longlines, vertical handlines, gill nets, traps, and trawls (Fischer, 1978; Manooch, 1984). Consumer fears associated with tapeworm infestations and ciguatera poisoning in amberjacks, that only a few years ago curtailed marketability, have either been forgotten or dismissed, as commercial landings and sales have increased dramatically, particularly in the Gulf of Mexico. Landings in millions of pounds for that area have climbed from <0.10 in 1970 to 2.60 in 1988, valued at 1.6 million dollars (Beasley, 1993) largely due to the popularity of smoked amberjack. Landings declined from 1989-1992. Recreational catch statistics are probably not precise, but recreational catches are thought to equal or surpass the commercial catch (Berry and Burch, 1979).

As fishing effort and landings for greater amberjack have increased, fishery managers have assessed the status of the species along the southeastern United States and Gulf of Mexico. However, despite the growing popularity of the species, little is known about the life history (Beasley, 1993).

Materials and Methods

Fish were sampled from headboats operating in the Gulf of Mexico from Naples, Florida, to Port Aransas, Texas, from 1988 to 1993. Sagittal otoliths from 340 fish were used in the study, and most (53%) were from greater amberjack caught off Texas (71% of these were from Port Aransas), while 46% were from northwest Florida and Alabama, and 1% from Louisiana. Fork length (FL) and total length (TL) were recorded in millimeters for each fish. Since most fish were eviscerated at sea, they were usually not weighed or sexed.

The greater amberjack otolith is small and difficult to locate, extract, and read. To determine age, we first examined whole otoliths, which were immersed in clove oil, placed in a black watch glass, illuminated by reflected light, and examined at 12X through a dissecting microscope. After counting the number of rings, we measured distances from the otolith core to the distal edge of each ring, from the core to the otolith edge, and from the last ring to the otolith edge. We used a measuring plane similar to that used by Manooch et al. (1987) for king mackerel, *Scomberomorus cavalla*. We also prepared three transverse sections for each fish about 0.3-mm thick using a low-speed circular saw. Prior to sectioning, otoliths were embedded in epoxy resin in bullet-shaped molds. Rings on otolith sections were viewed at 25X, counted and compared with counts made while reading the otoliths whole. To improve the legibility of some sections, we polished them with power-driven lapidary machines using 12.5-μm and 3-μm aluminum-oxide grit suspended in distilled water.

To evaluate if rings on otoliths were annuli (i.e., formed once each year) we conducted marginal increment analyses. Distances from the last ring to the otolith edge were plotted by month. We also plotted the percentage of otoliths with zero increments by month.

Measurements of fish length and weight were used to derive length conversion equations: $FL = a + b\,(TL)$, and $TL = a + b\,(FL)$, and weight-length equations: $W = aTL^b$ and $W = aFL^b$. The weight-length regressions were performed on log transformed data and corrected for the log normal bias using 1/2*MSE (mean squared error) (Beauchamp and Olson, 1973).

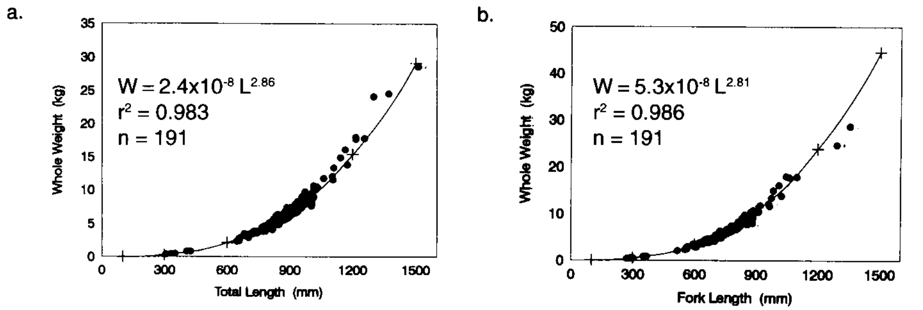


Figure 1. Weight-length relationships (a. whole weight-total length, and b. whole weight - fork length for greater amberjack collected from the Gulf of Mexico.

Fish length and otolith radius measurements were used to determine the relationship of the otolith radius (OR) to the size of the fish (FL and TL): FL or TL = a + b (OR). When fish size-otolith size relationships were obtained, fish sizes at earlier ages were back-calculated (Everhart et al., 1975; Ricker, 1975).

Theoretical growth models provide growth parameters such as mean asymptotic length (L_∞), and growth coefficient (K) that may be used in constructing dynamic pool models. The most frequently used growth model is the von Bertalanffy equation: $Lt = L_\infty\ (1\text{-}e^{-K(t-t_0)})$ where L_t = length at age t (usually in years), and t_0 = time when fish length equals 0 according to the fitted curve. The growth equation was fitted to all back-calculated lengths using the Marquardt nonlinear iterative procedure (SAS Institute, 1982) to obtain estimates for L_∞, K, and t_0.

A catch curve was used to estimate instantaneous total mortality (Z) (Everhart et al., 1975; Ricker, 1975; Beverton and Holt, 1957) based on the age distribution of fully recruited greater amberjack. We used an age-length key to obtain age frequencies for fish from which otoliths were unavailable. The $\log_e$ of the age frequency in the catch was plotted on age, and the slope of the linear descending right limb of the curve was used as an estimate of the mean instantaneous total mortality (Z).

Results and Discussion

Length Conversions. — Prediction equations for relating total lengths (TL) and fork lengths (FL) were:

FL = -17.73 + 0.88 (TL); r^2 = 0.995 (n = 269), and

TL = 24.23 + 1.12 (FL); r^2 = 0.995.

Beasley's (1993) conversion equation for the species collected from Louisiana waters was : TL = 1.14 FL + 13.05; r^2 = 0.99, where FL = fork length in millimeters and TL = total length in millimeters.

Weight-Length Relationships. — Our length-length equations were used to assign lengths to those fish where either total or fork length had not been recorded. With both lengths available, we derived the following equations to predict weight, W, (kg) from total and fork length in mm, respectively:

$W = 2.4 \times 10^{-8}\ TL^{2.86}$; n = 191; r^2 = 0.983 (Fig. 1a) and $W = 5.3 \times 10^{-8}\ FL^{2.81}$; n = 191, r^2 = 0.986 (Fig. 1b).

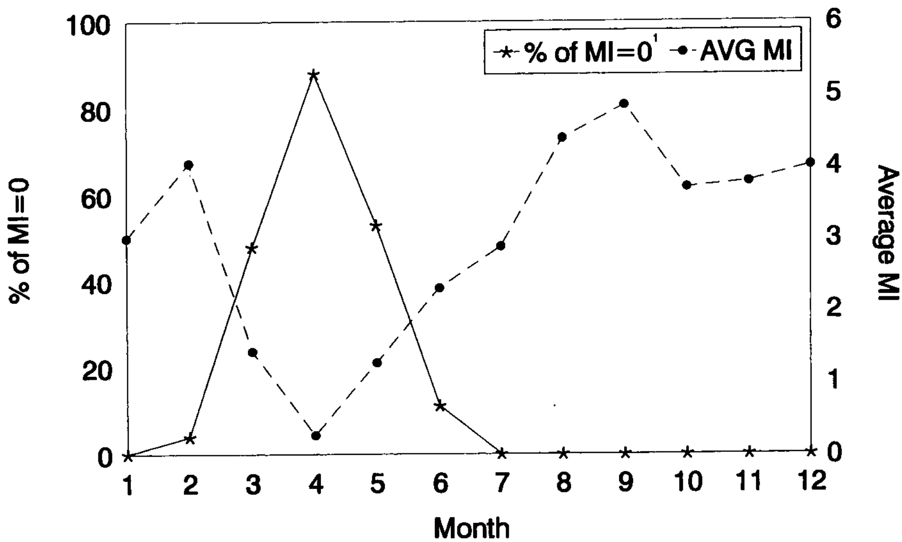
The sample size for weights was relatively small because many of the fish were eviscerated at sea. Burch (1979) derived the following weight-length relationship for greater amberjack from the Florida Keys:

Table 1. Back calculated total lengths (mm) of greater amberjack (n = 225) from the Gulf of Mexico

Age (yr)	n	Observed length ± 1 SD	Annulus														
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	16	488 ± 82	406														
2	13	648 ± 59	417	613													
3	37	820 ± 63	422	617	745												
4	74	869 ± 55	419	618	744	842											
5	41	926 ± 57	416	613	746	841	918										
6	20	996 ± 63	392	605	732	834	905	967									
7	12	1077 ± 73	411	599	725	823	907	970	1021								
8	4	1221 ± 50	409	621	727	825	899	956	1013	1054							
9	4	1260 ± 38	417	605	735	842	932	1005	1071	1103	1136						
10	1	1255	417	613	744	842	940	1005	1071	1103	1136	1169					
11	1	1385	417	678	776	874	1005	1071	1136	1169	1201	1234	1267				
12	1	1371	384	613	776	874	972	1038	1103	1169	1201	1234	1267	1299			
15	1	1512	449	613	744	842	940	1005	1071	1136	1169	1201	1234	1267	1299	1332	1365
Weighted mean			415	614	742	839	915	976	1041	1100	1156	1209	1256	1283	1299	1332	1365
lengths ± 1 SE			3	3	3	4	6	7	12	17	12	16	11	16	-	-	-
Increments				199	128	97	76	61	65	59	56	53	47	27	16	33	33

Table 2. Back calculated fork lengths (mm) of greater amberjack (n = 225) from the Gulf of Mexico

Age(yr)	n	Observed length ± 1 SD	Annulus														
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	16	419 ± 70	342														
2	13	556 ± 53	351	524													
3	37	706 ± 55	355	528	642												
4	74	751 ± 48	353	529	641	727											
5	41	801 ± 51	350	524	642	726	795										
6	20	861 ± 54	329	517	630	720	784	839									
7	12	932 ± 69	346	512	623	710	785	841	886								
8	4	1068 ± 49	343	532	626	713	778	828	879	915							
9	4	1104 ± 40	351	517	633	727	807	872	930	959	988						
10	1	1098	351	524	640	727	814	872	930	959	988	1017					
11	1	1210	351	582	669	756	872	930	988	1017	1046	1075	1104				
12	1	1291	322	524	669	756	843	901	959	1017	1046	1075	1104	1133			
15	1	1355	380	524	640	727	814	872	930	988	1017	1046	1075	1104	1133	1162	1191
Weighted mean lengths ± 1 SE			349 2	526 3	639 3	725 4	793 5	846 7	903 11	956 15	1006 11	1053 14	1094 10	1118 14	1133 -	1162 -	1191 -
Increments				177	113	86	68	53	57	53	50	47	41	24	15	29	29



1. MI = 0 means margin was opaque

Figure 2. Marginal increment (MI) analysis of greater amberjack, ages 0-15, collected from the Gulf of Mexico.

$W = 6.40 \times 10^{-5} L^{2.842}$; $r^2 = 0.91$, where W = weight in pounds, and L = fork length in centimeters.

AGE. — Whole otoliths were not useful for aging greater amberjack. Rings were unclear, and could not be easily counted and measured. Sectioned otoliths were easier to "read", but were more difficult to interpret than other species studied by the senior author.

The usefulness of any hard structure to estimate fish age should first be demonstrated. Critical to this decision is that there must be a positive relationship between the size of the fish and the size of the structure, and age marks must be periodically formed and consistently located on the hard part. Three observations support the use of sectioned otoliths for aging greater amberjack and validate sagittal rings as annual marks. First, the mean lengths of the fish progressively increased as the number of rings (age) increased (Tables 1, 2). Second, there was a strong correlation between otolith radii and fish lengths ($r^2 = 0.83$). Third, marginal increment analyses by month generally showed a marked decrease in marginal increment in late winter - early spring (March to May) (Fig. 2) and validates the formation of rings as annular marks. This trend was similar to that reported by Burch (1979): "Marginal increment was greatest in December 1977. It declined rapidly from January to March and then increased until December." Beasley (1993) confirmed annu-

Table 3. Theoretical growth parameters with 95 percent confidence limits (C.I.) for greater amberjack, TL and FL

Category	L_∞	C.I.	K	C.I.	t_o	C.I.
TL	1272	1241-1304	0.227	0.213-0.242	-0.793	-0.878-(-)0.708
FL	1109	1081-1137	0.227	0.213-0.242	-0.720	-0.802-(-)0.638

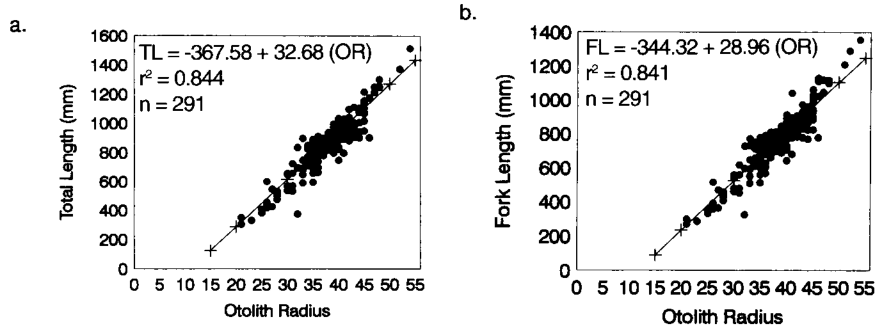


Figure 3. Length-otolith radius relationships (a. total length- otolith radius, and b. fork length-otolith radius) for greater amberjack collected from the Gulf of Mexico.

lar ring formation after examining six greater amberjack whose otoliths were marked with oxytetracycline. The annuli were formed between November and March.

We aged greater amberjack from 0 to 15 yrs. Greater amberjack collected off Louisiana by Beasley (1993) were also aged to age 15. Burch (1979) estimated the maximum age of the species at age 10 yrs by counting rings on the scales of fish from the Florida Keys. However, recent trends in fish age analysis place more significance on ages determined from otoliths than scales, as scale edges erode causing underestimates of true age.

BACK-CALCULATED GROWTH. — Lengths at age were back-calculated using otolith radius - fish length regressions:

TL = -367.58 + 32.68(OR); n = 291; r^2 = 0.84 (Fig. 3a), and FL = -344.32 + 28.96(OR); n = 291; r^2 = 0.84 (Fig. 3b).

Table 4. Comparison of our average observed, back-calculated (weighted mean), and theoretical lengths (TL and FL) at age in mm for greater amberjack from the Gulf of Mexico

	TL (mm)			FL (mm)		
Age	Observed	Calculated	Theoretical	Observed	Calculated	Theoretical
1	488	415	426	419	349	359
2	649	614	598	556	526	511
3	820	742	735	706	639	633
4	869	839	844	751	725	729
5	926	915	931	801	793	806
6	996	976	1000	861	846	868
7	1077	1044	1056	932	903	917
8	1221	1100	1100	1068	956	956
9	1261	1156	1135	1104	1006	987
10	1255	1209	1163	1098	1053	1012
11	1385	1256	1185	1210	1094	1031
12	1371	1283	1203	1291	1118	1047
13	-	1299	1217	-	1132	1060
14	-	1332	1228	-	1162	1070
15	1512	1365	1237	1355	1191	1078

Table 5. Theoretical lengths at age (FL, mm) for greater amberjack from the Gulf of Mexico estimated in this present study compared to those obtained by Beasley (1993) in Louisiana and Burch (1979) in southeast Florida

Age	Present Study*	Beasley (1993)+	Burch (1979)#
1	359	495	411
2	511	690	607
3	633	842	773
4	729	961	912
5	806	1055	1029
6	868	1127	1127
7	917	1184	1209
8	956	1229	1278
9	987	1264	1337
10	1012	1291	1386
11	1031	1312	1427
12	1047	1329	1461
13	1060	1342	1490
14	1070	1352	1515
15	1078	1360	1535

*$L_t = 1109\ (1-e^{-0.227\ (t+0.7198)})$
+$L_t = 1389\ (1-e^{-0.246\ (t+0.791)})$
#$L_t = 1643\ (1-e^{-0.174\ (t+0.653)})$

By substituting the means of the distance from the focus for OR in these equations, we estimated the mean fish length (TL and FL) at the time of each annulus formation and the mean annual growth increment at each age for all fish (Tables 1, 2).

Growth in length was relatively fast for the first 4 yrs of life, but generally declined through ages 5 to 15 (Tables 1, 2). Annual growth increments TL(mm) for ages 1 to 5 were 415, 199, 128, 97 and 76 (Table 1). The rate at which greater amberjack continue to grow between their 14th and 15th years suggests that the species lives longer than 15 yrs.

THEORETICAL GROWTH. — The von Bertalanffy growth curve was fitted to all back-calculated fish lengths from Tables 1 and 2 (Everhart et al., 1975; Ricker, 1975) using SAS non-linear least squares procedure (SAS Institute, 1982), and growth parameter estimates with 95% asymptotic confidence intervals (C.I.) were obtained (Table 3 and Fig. 4):

$TL_t = 1272\ (1-e^{-0.2272(t+0.7931)})$, and $FL_t = 1109\ (1-e^{-0.2270(t+0.7198)})$.

Burch (1979) derived the following growth equation for greater amberjack from South Florida:

$FL_t = 1643\ (1-e^{-0.174(t+0.653)})$.

More recently, Beasley (1993) derived the following equation for the species collected off Louisiana:

$FL_t = 1389\ (1-e^{-0.246(t+0.791)})$.

Observed mean lengths at capture, back-calculated, and theoretical lengths at age are compared in Table 4. Our lengths at age are consistently smaller than those presented by Burch (1979). There are several possible explanations for the disparity. First, greater amberjack from South Florida may be isolated from those in the northern Gulf of Mexico

Table 6. Greater amberjack age-fish length (TL, mm) distribution for fish collected from the Gulf of Mexico headboat fishery from 1988-1993

Length class 50mm	Age 1	2	3	4	5	6	7	8	9	10	11	12	15	Total
350	2(100.0)*													2
400	5(100.0)													5
450	2(100.0)													2
500	4(66.67)	2(33.33)												6
550	2(50.00)	2(50.00)												4
600	2(40.00)	3(60.00)												5
650		8(80.00)	2(20.00)											10
700		3(30.00)	6(60.00)	1(10.00)										10
750			8(38.10)	11(52.38)	2(9.52)									21
800			19(33.93)	32(57.14)	5(8.93)									56
850			12(24.49)	30(61.22)	7(14.29)									49
900			4(6.35)	26(41.27)	23(36.51)	9(14.29)	1(1.59)							63
950				7(22.58)	15(48.39)	7(22.58)	2(6.45)							31
1000				1(6.67)	6(40.00)	4(26.67)	4(26.67)							15
1050						6(54.55)	5(45.45)							11
1100						2(33.33)	4(66.67)							6
1150							2(33.33)	4(67.67)						6
1200							1(25.00)	1(25.00)	2(50.00)					4
1250								2(40.00)	2(40.00)	1(20.00)				5
1350											1(50.00)	1(50.00)		2
1500													1(100.0)	1
N	17	18	51	108	58	28	19	7	4	1	1	1	1	314

*Number of fish and in parenthesis ( ) is percentage of length class

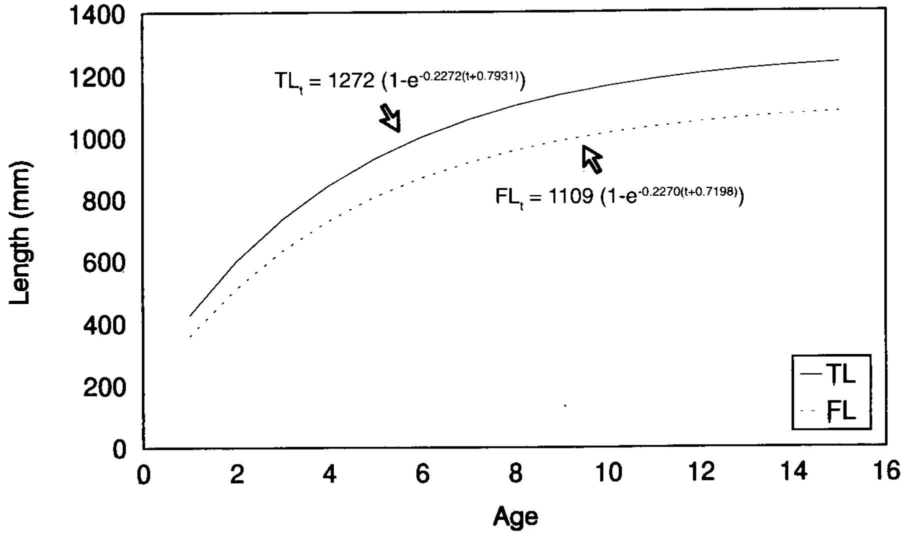


Figure 4. Theoretical lengths (TL and FL, mm) at age for greater amberjack from the Gulf of Mexico.

and grow more rapidly. Second, if fish from South Florida mix with the fish in the northern Gulf of Mexico, differences in growth may be temporal, and attributable to compensatory changes related to increased fishing and environmental pressures on the species between the late 1970s (Burch, 1979) and the present. Or third, one of the two studies may have aging inaccuracies. We suspect that the last scenario is the most plausible. Mean back-calculated and theoretical lengths at specific ages for the two studies (Table 5), appear staggered, i.e., a 1-yr (ring) difference. For example, the mean length age 1 obtained by Burch (1979) is similar to the mean length that we calculated for age 2 fish. Also, Burch used scales to age this species. We consider this method to be unreliable for aging greater amberjack.

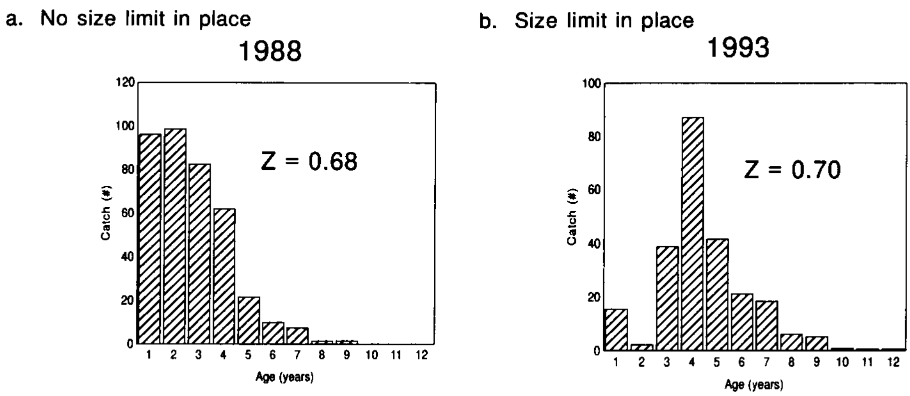


Figure 5. Catch-at-age for 1988 (a.) and 1993 (b.) Gulf of Mexico headboat landings (based on fish age - total length key).

Table 7. Greater amberjack age-fish length (FL, mm) distribution for fish collected from the Gulf of Mexico headboat fishery from 1988-1993

Length Class 50mm	Age 1	2	3	4	5	6	7	8	9	10	11	12	15	Total
300	2(100.0)*													2
350	6(100.0)													6
400	2(100.0)													2
450	4(57.14)	3(42.86)												7
500	2(40.00)	3(60.00)												5
550	1(10.00)	8(80.00)	1(10.00)											10
600		4(28.57)	9(64.29)	1(7.14)										14
650			11(40.74)	14(51.85)	2(7.41)									27
700			16(26.67)	37(61.67)	7(11.67)									60
750			12(16.00)	39(52.00)	20(26.67)	3(4.00)	1(1.33)							75
800			2(4.26)	16(34.04)	16(34.04)	12(25.53)	1(2.13)							47
850					13(61.90)	4(19.05)	4(19.05)							21
900				1(7.69)		7(53.85)	5(38.46)							13
950						2(33.33)	4(66.67)							6
1000							3(37.50)	4(50.00)	1(12.50)					8
1050							1(50.00)			1(50.00)				2
1100								3(50.00)	3(50.00)					6
1200											1(100.0)			1
1250												1(100.0)		1
1350													1(100.0)	1
N	17	18	51	108	58	28	19	7	4	1	1	1	1	314

*Number of fish and in parenthesis ( ) is percentage of length class.

MORTALITY. — Mortality estimates may be obtained after fish have been aged and size or age distribution in the catch is known. We used fish length-fish age keys (Tables 6, 7) to assign ages to greater amberjack harvested by the headboat fishery. Regressions of age frequency in catch plotted on age for greater amberjack were fitted to the data for all ages from the modal age through the greatest age in the sample.

Catch curves from the Gulf of Mexico headboat fishery were plotted for 1988 and 1993 (Fig. 5). In 1988 there was no minimum size limit in place; in 1993, fish less than 28 in could not be retained. There are two problems with our data: 1) they are collected only from one sector of the fishery, headboats, and 2) most of the fish were captured off Texas. Headboat anglers, because of fishing conditions and lack of experience, might be less likely to land large amberjack than small ones compared with commercial fishermen. Thus our data may overestimate Z. Greater amberjack were fully recruited to the fishery at age 2 in 1988, but age 4 in 1993, probably because of size restrictions. Point estimates of the instantaneous total mortality rate (Z) were 0.68 for 1988 and 0.70 for 1993.

While there is no indication that greater amberjack are being overfished at the present time along the southeastern and Gulf of Mexico coasts of the United States (G. R. Huntsman, pers. comm.), Beasley (1993) presents evidence of this possibility. He found that greater amberjack off Louisiana may remain at a particular reef for a year or more. Tagging data and observations made by divers revealed that the species was observed and captured at the tagging site 9 mo after the fish were tagged. Beasley (1993) states that the strong attraction to reefs makes the species a likely candidate for overfishing.

ACKNOWLEDGMENTS

The authors wish to acknowledge the contributions of reviewers D. Ahrenholz, J. Smith, G. Huntsman, and J. Merriner of the NMFS, Beaufort Laboratory, and W. Richards, NMFS, Miami Laboratory. B. Harvey, NMFS, Beaufort Laboratory, provided clerical assistance. We are especially grateful to D. Vaughan, NMFS, Beaufort Laboratory for his consultations pertaining to the most appropriate theoretical growth equation for our data.

LITERATURE CITED

Beasley, M. L. 1993. Age and growth of greater amberjack, *Seriola dumerili*, from the northern Gulf of Mexico. M.S. thesis, Louisiana State University, Baton Rogue. 85 p.

Beauchamp, J. J., and J. S. Olson. 1973. Corrections for bias in regression estimates after logarithmic transformation. Ecology 54: 1403-1407.

Berry, F. H. and R. H. Burch. 1979. Aspects of the amberjack fisheries. Proc. Annu. Gulf Caribb. Fish. Inst. 31: 169-174.

Beverton, R. J. H. and S. J. Holt. 1957. On the dynamics of exploited fish populations. Fish. Invest. Ser. II. Mar. Fish. G. B. Minist. Agric. Fish. Food 19. 533 p.

Bohnsack, J. A., A. Brown, Jr. and D. Harper. 1989. Automated landings assessment for responsive management (ALARM): Gulf of Mexico commercial reef fish landings, June 1989. NOAA/NMFS- SEFC, Miami, Coastal Resources Division. Contribution No. CRD - 88/89. 16 p.

Burch, R. K. 1979. The greater amberjack, *Seriola dumerili*: Its biology and fishery off southeastern Florida. M.S. thesis, University of Miami, Coral Gables. 113 p.

Everhart, W. H., A. W. Eipper and W. D. Youngs. 1975. Principles of fishery science. Cornell University Press, Ithaca, New York. 228 p.

Fischer, W. 1978. FAO species identification sheets for fishery purposes, western central Atlantic (fishing area 31), Vol. II. Marine Resources Services, Fishery Resources and Environment Division, FAO Fisheries Department, Rome.
Manooch, C. S., III. 1984. Fisherman's guide to the fishes of the southeastern United States. North Carolina Museum of Natural History, Raleigh, North Carolina. 362 p.
_______________, S. P. Naughton, C. B. Grimes and L. Trent. 1987. Age and growth of king mackerel, *Scomberomorus cavalla*, from the U.S. Gulf of Mexico. Mar. Fish. Rev. 49: 102-108.
Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Bd. Can. 191. 382 p.
SAS Institute. 1982. SAS user's guide: Statistics. SAS Institute, Inc., Cary, North Carolina. 584 p.

DATE ACCEPTED: September 26, 1995.

ADDRESS: *National Marine Fisheries Service, Southeast Fisheries Science Center Beaufort Laboratory, Beaufort, North Carolina 28516, Phone: (919)728-8716, E-mail: cmanooch@Hatteras.bea.nmfs.noaa*